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VARIATIONS IN THE INTENSITY OF SOLAR RADIATION AT NORMAL INCIDENCE ON THE SURFACE OF THE EARTH

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This paper brings up to date three earlier summaries by Kimball [1 and 2] and Hand [3] of variations in the intensity of solar radiation at normal incidence on the earth's surface. The data summarized here are taken from stations in the United States only as in the previous paper by Hand, whereas Kimball used world-wide data. However, due to the incompleteness of data, this paper could not be based precisely on the same stations used by Hand. It is based instead on all available data for 1939–1952 for Blue Hill Observatory, Mass., Madison, Wis., Lincoln, Nebr., Table Mountain, Calif., Albuquerque N. Mex., and Boston, Mass.

Pyrheliometric measurements of normal incidence radiation are made at frequent intervals at selected stations only when the sky in front of the sun is cloudless. Commencing with Madison, Wis. in 1910 and continuing with Lincoln, Nebr. 1915; Blue Hill, Mass. 1932; Albuquerque, N. Mex., 1941; Boston, Mass., 1945; and Table Mountain, Calif., 1947, monthly normals for each principal air mass, for each station have been maintained. The sum of the monthly values of each air mass added to the accumulated total of that particular air mass since the station's inception is divided by the total number of observations over this period, thus obtaining a running normal. Dividing the actual monthly mean value by the running normal for each air mass, and multiplying by 100, the percent of normal for the month for the air mass was determined. The average of the percent of normal of the principal air masses was taken as the monthly percent of normal before smoothing. Next, these percents were smoothed by the formula $(a+2b+c)/4$ where b is the percent of normal for the current month, and a and c for the preceding and following months. The smoothed curves for all stations combined and for each station individually are shown in figure 1. The data for all stations combined are also given in table 1. Figure 1 and table 1 also give the yearly averages.

It is interesting to speculate on the causes of some of the major variations in the curves of figure 1. Normal incidence insolation is attenuated in various ways before its receipt at the surface of the earth. Perhaps the most important and certainly the one with the most lasting effect is the presence of minute particles of volcanic dust, suspended in the atmosphere, usually produced by a violent volcanic eruption. Months and sometimes years are required before these particles settle to the ground, as shown in the solar radiation measurements for the years after the eruption of Krakatoa in 1883 [1 and 4]. From 1939 to 1952 just one known instance of volcanic dust occurred over the United States, and this was confined to the eastern section, reaching as far west as New Orleans and as far north as Boston, in June 1951. This volcanic dust, observed first over the Caribbean [5], was from an eruption in the Cape Verde Islands. Cloudiness at Blue Hill Observatory prevented any solar observations of this phenomenon, and no other recording station was in the area affected by this dust. However, shortly after this time a depression appeared in the curve for Blue Hill and continued until January 1952.

A second and more frequent vitiation in the form of smoke and haze, although of short duration, depletes insolation to a very marked degree. By far the greatest number of negative deviations during this period were caused by the presence of smoke and haze, usually local

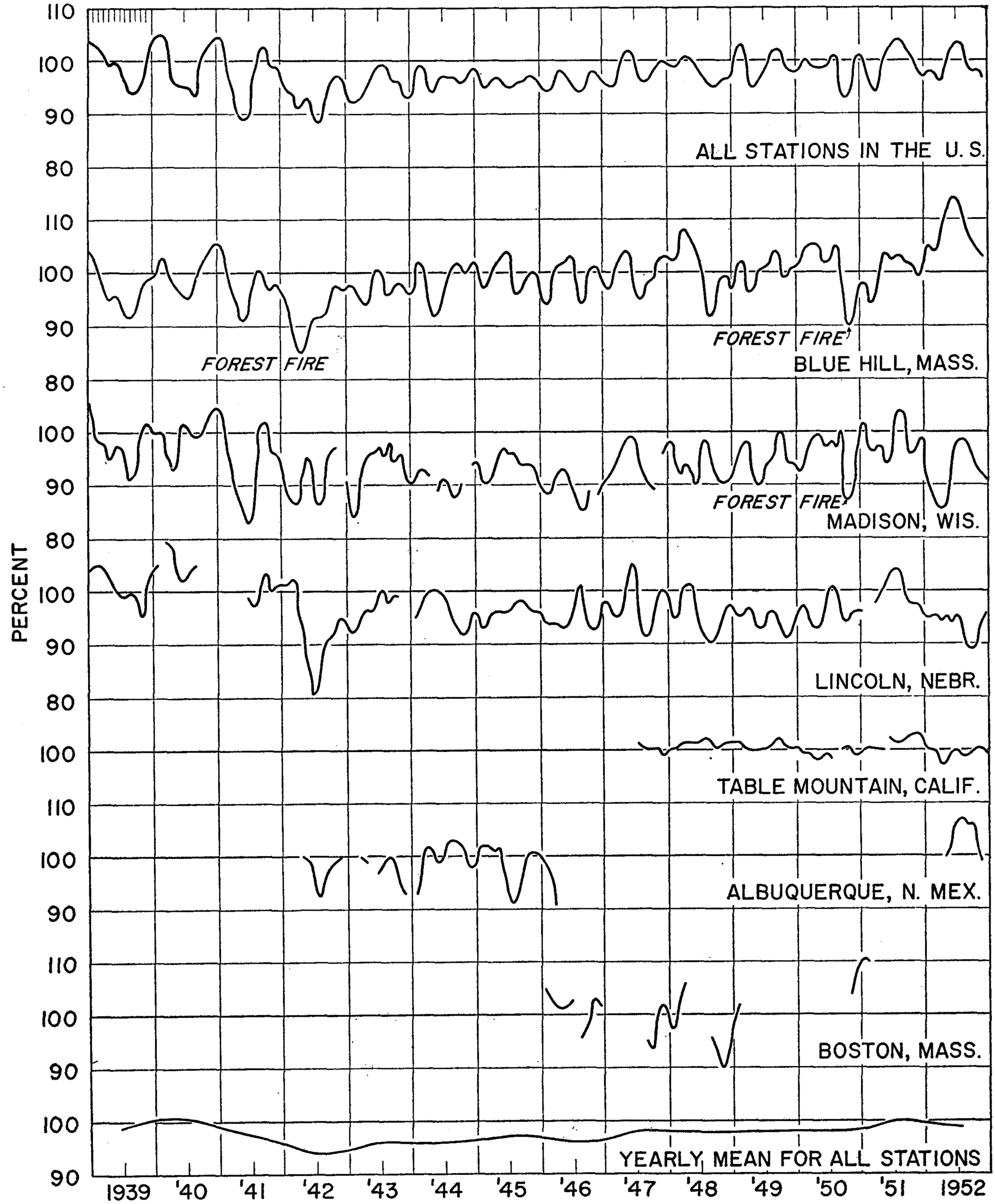

FIGURE 1.—Smoothed percents of normal solar radiation at normal incidence at stations in the United States, 1939–1952. The first seven curves are based on monthly percents of normals; the final curve is based on the yearly means of the monthly values. Vertical grid lines indicate January of each year; center ticks, July. Monthly spacing is indicated by ticks in upper left corner.

TABLE 1.—*Percents of normal incidence radiation at all stations* in the United States, 1939–1952*

	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	Average
January	105	101	106	97	94	93	99	98	97	100	97	97	101	98	99
February	103	102	104	96	91	96	97	95	95	97	99	98	101	97	98
March	101	102	100	94	94	99	95	94	96	99	100	99	95	98	98
April	100	102	95	90	96	98	97	97	97	102	97	99	97	96	97
May	98	99	91	92	96	96	98	99	101	100	95	99	99	99	97
June	98	99	88	94	97	95	98	97	102	98	96	98	100	101	97
July	98	100	92	89	99	97	97	95	99	99	97	99	102	102	97
August	95	100	95	89	99	97	97	92	95	97	98	101	103	101	97
September	94	99	101	93	98	97	97	94	95	95	100	98	103	99	97
October	95	101	101	95	97	96	98	95	95	94	100	94	101	99	97
November	96	102	98	97	96	93	98	99	99	95	96	95	99	98	97
December	100	104	98	97	95	97	97	96	100	96	97	98	99	97	98
Mean	99	101	97	94	96	96	97	96	98	98	98	98	100	99	
Departure	−01	+01	−03	−06	−04	−04	−03	−04	−02	−02	−02	−02	00	−01	

*Data from following stations: Blue Hill Observatory, Mass., Madison, Wis., Lincoln, Nebr., Table Mountain, Calif., Albuquerque, N. Mex., and Boston, Mass.

in nature and origin. These vitiations often occur with the presence of a subsiding high pressure system when smoke, haze, and traffic dust of the cities are trapped by a temperature inversion aloft.

A very important source of smoke that prevents the passage of solar radiation through the atmosphere is forest fires. Smoke from these fires may be lifted to the tropopause and may travel for great distances. In late September 1950, a forest fire [6 and 7] occurred in northwest Canada, and a week later evidence of this smoke was found as far east as Germany and Poland. Smoke of this magnitude and density has practically the same effect on insolation as a thin water vapor cloud [8] and radiation values at Blue Hill and Madison for September and October showed sharp declines as a result.

Dust storms, another factor in the depletion of solar energy, of the intensity of those in the spring of 1934 [9] in South Central United States, have not been encountered during the 1939–1952 period. There is no evidence of any important depletion of solar energy as a result of dust storms during this period.

Explanations of minor fluctuations in the curves cannot be attempted here; however for the more radical departures the following causes are suggested as possibilities. A sharp depression in the curve for all stations combined occurred beginning in January 1941 and climaxing in June 1941. This drop was due for the most part to forest fires at Blue Hill, and persistent smoke and haze at both Blue Hill and Madison. From October 1941 to May 1947, values of normal incidence radiation were consistently lower than average. The increase in manufacturing, and the conversion from oil to soft coal by many homes and factories during World War II may have contributed greatly to these depletions. It was during this period, in August 1942, that the greatest departure from normal took place since the eruption of Katmai in 1912.

The possibility that some of the air mass readings at Madison and Blue Hill were taken through thin clouds is not remote. At Madison over the period July 1941 to October 1947 solar halos were recorded on 27 different days on which normal incidence measurements were also made. Although it is not possible to determine whether or not thin clouds were present at the air mass times, it is possible that on some occasions they did coincide. At Blue Hill it was common practice to take normal incidence readings from any smooth curve, and over this period it is a distinct possibility that in some few measurements the radiation was attenuated by clouds.

REFERENCES

1. H. H. Kimball, "Volcanic Eruptions and Solar Radiation Intensities," *Monthly Weather Review*, vol. 46, No. 9, August 1918, pp. 355–356.
2. H. H. Kimball, "Variations in Solar Radiation Intensities Measured at the Surface of the Earth," *Monthly Weather Review*, vol. 52, No. 11, November 1924, pp. 527–529.
3. Irving F. Hand, "Variation in Solar Radiation Intensities at the Surface of the Earth in the United States," *Monthly Weather Review*, vol. 67, No. 9, September 1939, pp. 338–340.
4. H. Wexler, "On the Effects of Volcanic Dust on Insolation and Weather," *Bulletin of the American Meteorological Society*, vol. 32, No. 1, January 1951, pp. 10–15.
5. W. F. Brown, "Volcanic Ash Over the Carribbean, June 1951," *Monthly Weather Review*, vol. 80, No. 4, April 1952, pp. 59–62.
6. H. Wexler, "The Great Smoke Pall of Sept. 24–30, 1950," *Weatherwise*, vol. 3, No. 6, December 1950, pp. 129–135.
7. C. D. Smith, "The Widespread Smoke Layer From Canadian Forest Fires During Late September 1950," *Monthly Weather Review*, vol. 78, No. 9, September 1950, pp. 180–184.
8. Rudolf Penndorf, "On the Phenomenon of the Colored Sun, Especially the 'Blue' Sun of September 1950," *Geophysical Research Papers* No. 20, Air Force Cambridge Research Center, Cambridge, Mass., April 1953.
9. Irving F. Hand, "The Character and Magnitude of the Dust Cloud which Passed over Washington, D. C., May 11, 1934," *Monthly Weather Review*, vol. 62, No. 5, May 1934, pp. 156–157.